Vertical Waterwheel-Driven Generators

62.5 kv-a. to 3000 kv-a.

GENERAL ELECTRIC COMPANY
Schenectady, N. Y.

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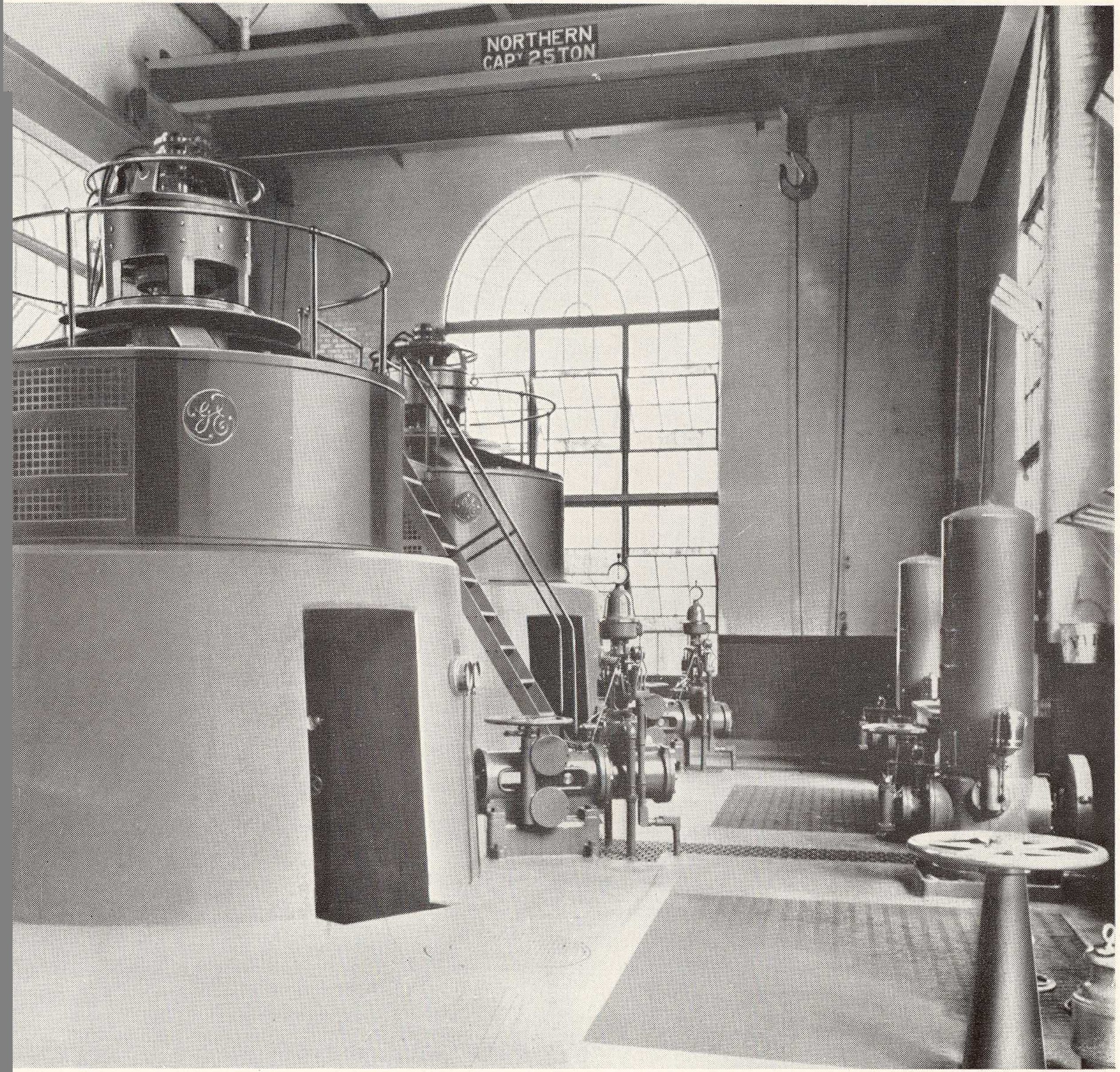
MODERN electric equipment has made practicable the development of much water power which in the past could not be used on account of high production costs.

Many of the easily accessible, large, water-power sites have been developed, but there remains a vast quantity of available water power suitable for driving small and medium-sized generators. In addition to these undeveloped sites, there are many old plants whose equipment could be replaced to advantage.

Remarkable advance has been made in the last few years in the design and manufacture of vertical waterwheels for low heads. These turbines, combined with the modern vertical generators, make units that are far simpler, more reliable, and more efficient than the old style of installation.

In the manufacture of these generators, the General Electric Company with its manufacturing facilities, large corps of specialists, and wide experience, is preëminent. With experience extending over forty years in the design, construction, and installation of waterwheel-driven generators, this Company is now producing units ranging in capacity from 30 to 77,500 kv-a. The total capacity of the machines of this class furnished by the General Electric Company is in excess of 8,000,000 kv-a.

In addition to waterwheel-driven generators, the General Electric Company manufactures the electric apparatus necessary for the complete equipment of hydroelectric stations. The services of the Company's engineers are always at the disposal of prospective purchasers to assist in selecting apparatus which will afford safety and reliability in operation and the most effective utilization of water power.



Typical Hydroelectric Station

Features of G-E Generator Design

STATOR

THE stator frame is fabricated from steel plates of a suitable thickness. The plates, previously rolled to shape, are welded together to form a rigid structure. Rectangular openings with perforated covers provide air passages in the outer periphery of the frame. When required by shipping limits, the frame is split into sections held together by bolts, which are supported by carefully fitted bars welded to the frame. The joints of split frames come in the center of the ventilating openings, to provide accessibility to the joint bolts.

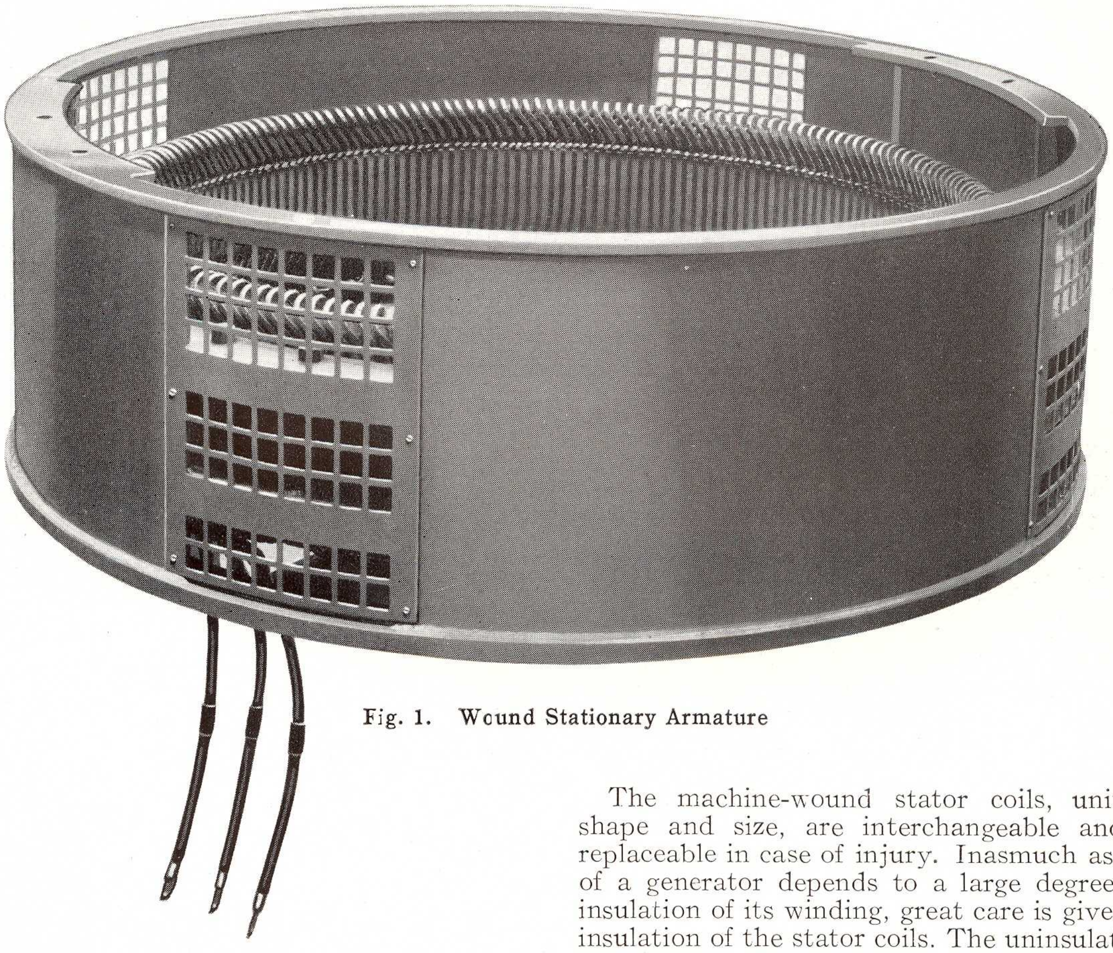


Fig. 1. Wound Stationary Armature

The core is securely clamped to the frame by means of heavy through bolts. Supports at the ends of the core firmly clamp the teeth, preventing abrasion of the coil insulation and vibration of the laminations. These clamping fingers allow free circulation of air through the ends of the coils. To provide for circulation of air through the core, ducts, open at both ends, are formed by suitable spacing blocks inserted at intervals between the laminations.

The core itself consists of accurately punched laminations of high-grade silicon steel. The punchings are annealed and coated on both sides with insulating enamel, thus reducing both hysteresis and eddy-current losses. Special care is given to accurate die work in order to minimize filing of the slots. This feature is important, as filing slots defeats the purpose of insulating the laminations from one another; *i.e.*, to reduce eddy-current losses.

The machine-wound stator coils, uniform in shape and size, are interchangeable and easily replaceable in case of injury. Inasmuch as the life of a generator depends to a large degree on the insulation of its winding, great care is given to the insulation of the stator coils. The uninsulated coils are accurately molded in heated forms. The insulation of the coils is Class A as defined by the A.I.E.E. and consists of the best quality of varnished cloth. The coils are subjected to several dippings in varnish, each followed by a baking treatment. The slot portion receives a final protecting layer of cotton tape.

The use of a fractional instead of an integral number of slots per pole in the design of alternating-current generators gives a smooth wave form free from ripples, resulting in improved efficiency, good parallel operation, and a reduction in the possibility of disturbance on telephone lines in close proximity to the generator lines. This fact has been recognized by the General Electric Company for many years, and the use of fractional slots has been adopted in the manufacture of its alternating-current generators. Attention is called to the fact that the stator windings are designed with a reactance as high as is compatible with high efficiency and good voltage control. This minimizes the possibility of injury to the machine from short circuits which may occur on the line. In modern practice, low inherent regulation of an a-c. generator is of minor importance, as perfect voltage control is easily obtained by use of the G-E automatic voltage regulator.

on the rim alone, which is made of a material homogeneous throughout. The design of both rim and center is definite and exact instead of being indeterminate as when rim and arm divide the load.

For low speeds, a welded spider is sometimes used, and for small diameters, cast-iron and cast-steel spiders are still employed.

It is possible for a waterwheel without load to attain a runaway speed of the order of two times normal. The rotor of every G-E alternating-current waterwheel-driven generator is designed to withstand the runaway speed of the waterwheel to which it is coupled.

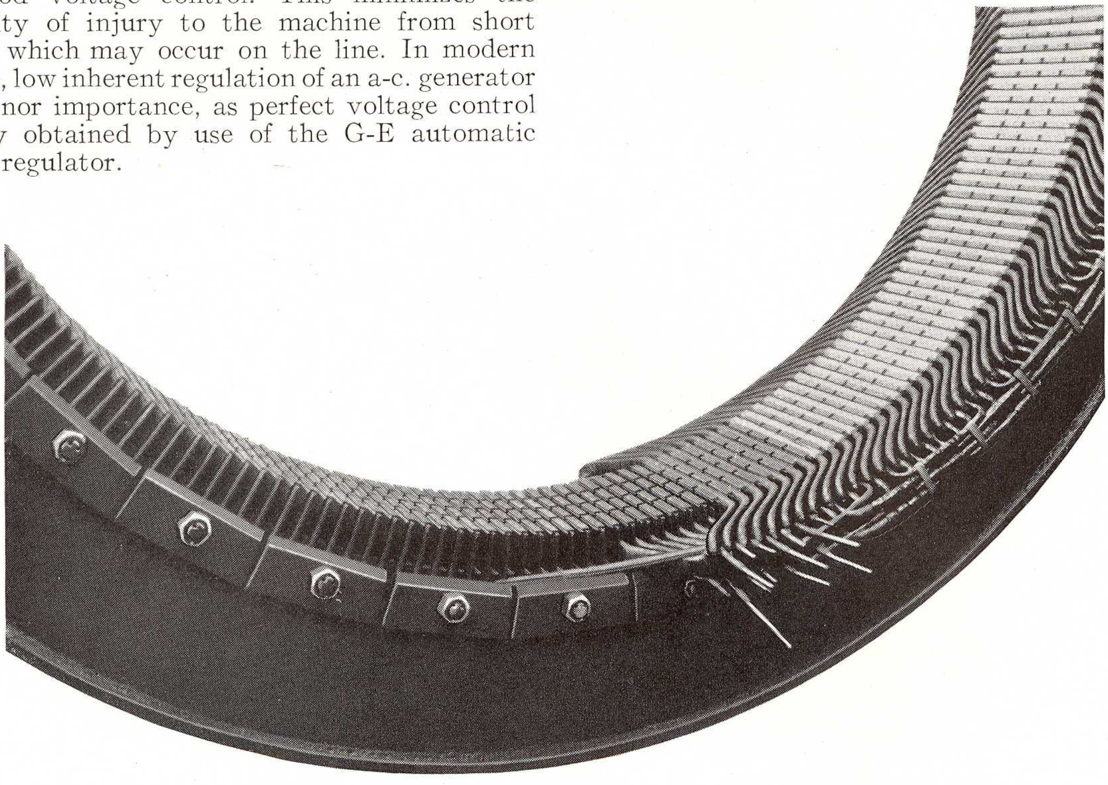


Fig. 2. Section of Stator Frame Showing Method of Installing Coils

ROTOR AND SHAFT

The revolving field, consisting of rotor spider, pole pieces, and windings, is keyed to a steel shaft of ample cross section to insure strength and rigidity. A flange-type coupling is forged integral with the shaft.

The rotor spider of the higher-speed machines is built up of circular steel plates, in which dovetail slots for the poles and the bore for the shaft have been punched. The plates are stacked to the required thickness and bound tightly together by through bolts to form a solid unit. As a final operation, the bore is machined.

For large-diameter, moderate-speed machines, the rotor spider consists of a rolled-steel rim shrunk on to a fabricated center with suitable dowels for torque. The rim is made in halves held together by link keys. With such a free rim, the principal stress, that caused by centrifugal force, is carried

A suitable braking surface is provided, and the spider is made stiff enough to support the weight of the entire rotating element when jacked or blocked at the braking surface.

The pole pieces are built up of thin steel laminations securely riveted together. On high-speed machines they are dovetailed into the rotor spider and locked by steel keys held in place by retaining plates. On low-speed and moderate-speed machines, they are secured to the spider by bolts.

In the smallest machines, field coils consist of copper wire wound directly on the pole pieces. On machines of larger size, the coils are of copper strip, wound on edge, so that each turn is exposed to the air. Each turn is insulated and the entire coil is insulated from the pole piece.

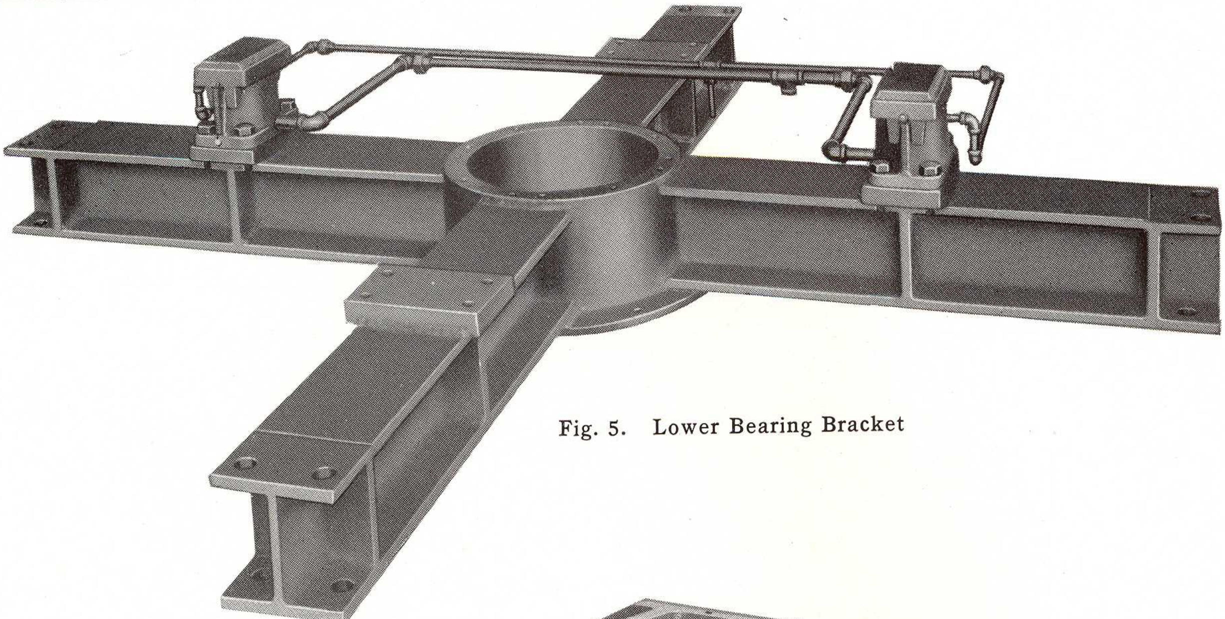


Fig. 5. Lower Bearing Bracket

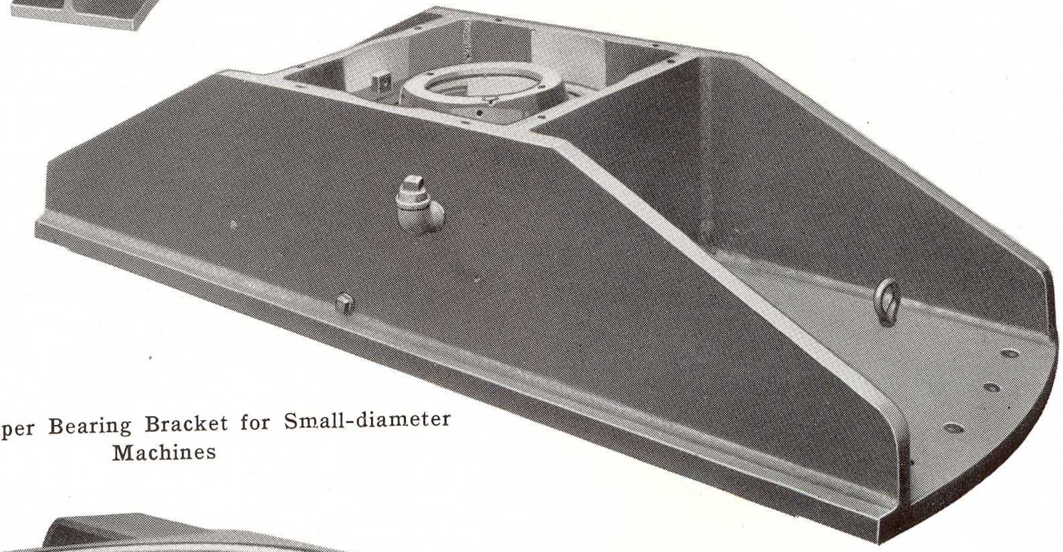


Fig. 6. Upper Bearing Bracket for Small-diameter Machines

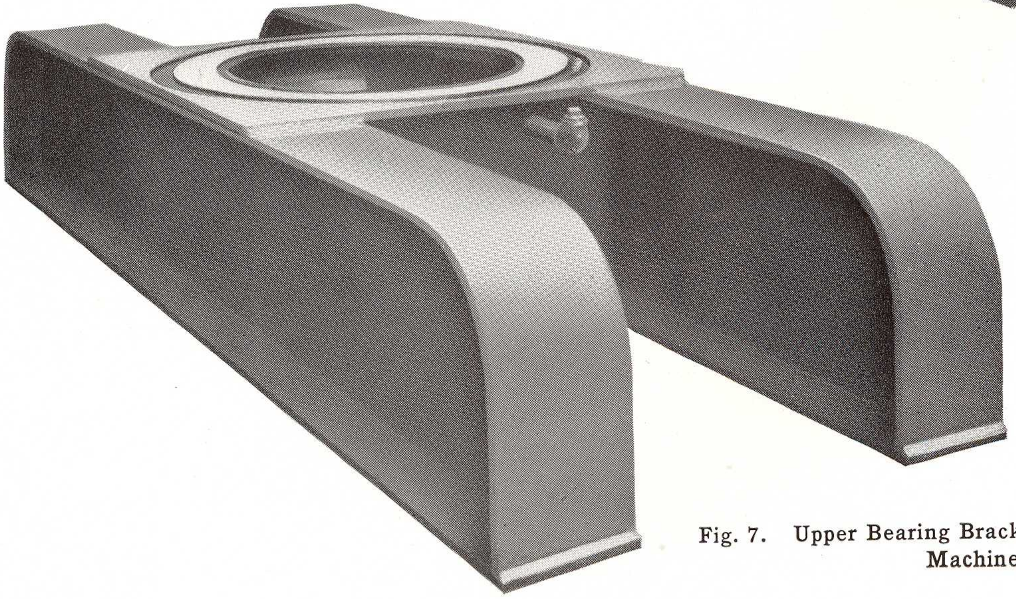


Fig. 7. Upper Bearing Bracket for Large-diameter Machines

LOWER BEARING BRACKET

For machines of small diameter, the arms of the lower bearing bracket are extended radially and are arranged to support the frame. By this design, a relatively larger pit diameter is obtained, and a single set of foundation caps under the bracket arms supports the entire unit. When desired, the bracket arms can be arranged to rest directly on a distance ring furnished with the waterwheel.

For machines of larger diameter, the lower bearing bracket is made of a diameter such that it can be lifted through the stator. This permits removal of waterwheel parts without disturbing the stator. Under this condition, separate sets of foundation caps are supplied for the lower bracket and the frame.

In either case, the bracket consists of three or more radial arms of structural I-beams welded to a central ring, which houses the lower guide bearing. Finished pads on the arms of the bracket accommodate brakes and jacks and are capable of supporting the entire rotating element. The babbitted lower guide bearing is split and can be removed without disturbing any other part of the machine. The lower bearing is lubricated by means of an oil pump located in a split oil pan, which is bolted to the bottom of the bearing bracket. The pump is of simple, strong construction and is operated by a cam on the generator shaft. The oil is forced through a flow-sight on the side of the machine to the upper part of the bearing and returns to the oil pan.

UPPER BEARING BRACKET

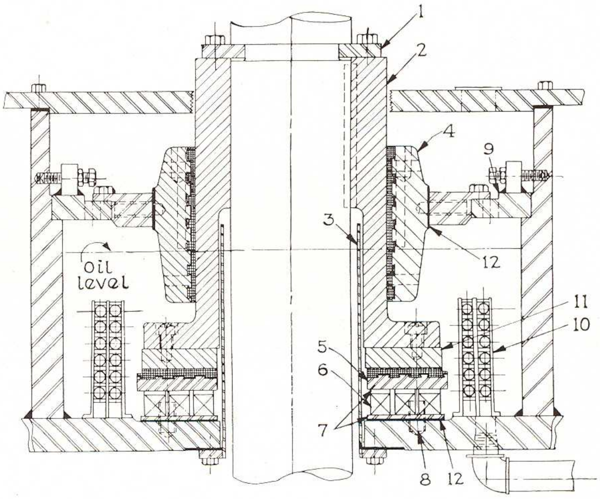
The upper bearing bracket, which supports the combined upper guide and spring-thrust bearing, is designed to carry the weight of the generator rotor, waterwheel runner, shaft, and hydraulic thrust with the minimum of deflection. For the smaller machines, the bracket is made of steel plates solidly welded together. For the larger machines, the bracket consists of two commercial girders rounded at the ends with a steel bearing housing welded in place. The bracket is bolted and doweled to the frame. Metal covers, bolted to the top ring of the frame, close the space around the bracket.

THRUST BEARING

The self-oiling combined upper guide and spring-thrust bearing is of the simplest type now in use. Spring-thrust bearings in successful operation are now carrying up to 1,400,000 pounds. Of the many types on the market, it is the only one which automatically adjusts itself to relieve high, local pressure that might occur as a result of inaccuracies of workmanship or alignment. When installed in the bearing, the springs receive an initial compression corresponding to normal load on the bearing. This insures the maintenance of the required clearance between the waterwheel runner and its casing when the hydraulic thrust is added to the weight of the rotating parts.

A constant and sufficient stream of oil is carried by centrifugal force over the thrust bearing surfaces. The guide bearing bears on the thrust collar and projects into the bath of oil in which the thrust bearing is immersed. Proper grooving of the guide bearing assures a supply of oil over its entire length. The combination is, therefore, self-contained, self-aligning, and self-oiling. To maintain safe oil temperatures, water cooling coils, when necessary, are installed in the bearing housing.

The thrust collar which supports the rotating element is keyed to the shaft. The vertical load is transmitted from the shaft to the thrust collar by a split retaining ring fitting into a circular groove in the shaft.



1. Split Retaining Ring
2. Thrust Collar
3. Oil-well Tube
4. Guide Bearing
5. Stationary Babbitted Ring
6. Springs
7. Clamps for Springs
8. Dowel Pin
9. Guide Bearing Support
10. Cooling Coils
11. Rotating Ring
12. Insulation

Fig. 8. Cross Section of Combined Upper Guide and Spring Thrust Bearing

STAIRWAY, HANDRAIL, AND PLATFORM

When desired, a stairway giving access to the top of the machine, together with a suitable handrail, can be supplied. On the larger sizes a separate platform can be furnished, but on the smaller sizes the cover plates at the top of the frame serve the same purpose.

COLLECTOR RINGS AND BRUSH RIGGING

The collector rings and brush rigging are mounted at the top of the unit. Proper bus rings support a suitable number of die-cast, box-type brush-holders, staggered to prevent uneven wear of the rings. Each brush-holder has a corrugated pin that indicates the compression of the spring. The brush pressure can be adjusted without the use of any tool. The brush-holders are not required to carry current, as the pigtails of the brushes are bolted to the bus rings.

BRAKES AND JACKS

All machines can be equipped with hydraulic brakes, which are mounted on the lower bearing bracket and bear against a suitable surface provided on the rotor spider. This type of brake consists of a piston moving in a carefully finished cylinder. Leakage is prevented by a cup leather packing at the bottom of the piston. An expansion spring keeps the packing tight against the cylinder. The brake shoes are of a metallic asbestos compound.

These brakes are operated preferably by air pressure of 100 to 125 pounds per square inch, but oil or water at the same pressure may be used. The piston and cylinder of the brakes are plated to prevent rusting when used with air or water. If it is desired to use the brakes as jacks to raise the rotor, oil or water at 1200 to 1500 pounds per square inch is used. When the rotor is raised sufficiently, a hinged metal block is placed under the rotor so that the hydraulic pressure can be released.

For small, low-speed machines, hand-operated mechanical brakes are usually supplied.

LIFTING DEVICE

Whenever desired, a lifting device of the trunnion type can be furnished for lifting the rotor. This device is assembled in place of the thrust collar and held by the same retaining ring.

RATINGS

G-E vertical waterwheel-driven generators are conservatively rated on the basis of energy output at 80 per cent power-factor and are, therefore, especially adapted for carrying either mixed lighting and power load or an induction-motor load alone.

Temperature rise is based on an ambient temperature of 40 deg. C., normal conditions of ventilation, and an altitude of 1000 meters (3300 ft.) or less. Corrections for variations from this altitude will be made by increasing the observed rise of temperature by 1 per cent for each 100 meters (330 ft.) deviation in altitude above 1000 meters.

At normal continuous rating and 0.8 power-factor, the temperature rise of each of the various parts, when determined by methods specified in the A.I.E.E. Standards No. 7, will not exceed the limiting values specified in the same standards (Table II) and shown in the following tabulation:

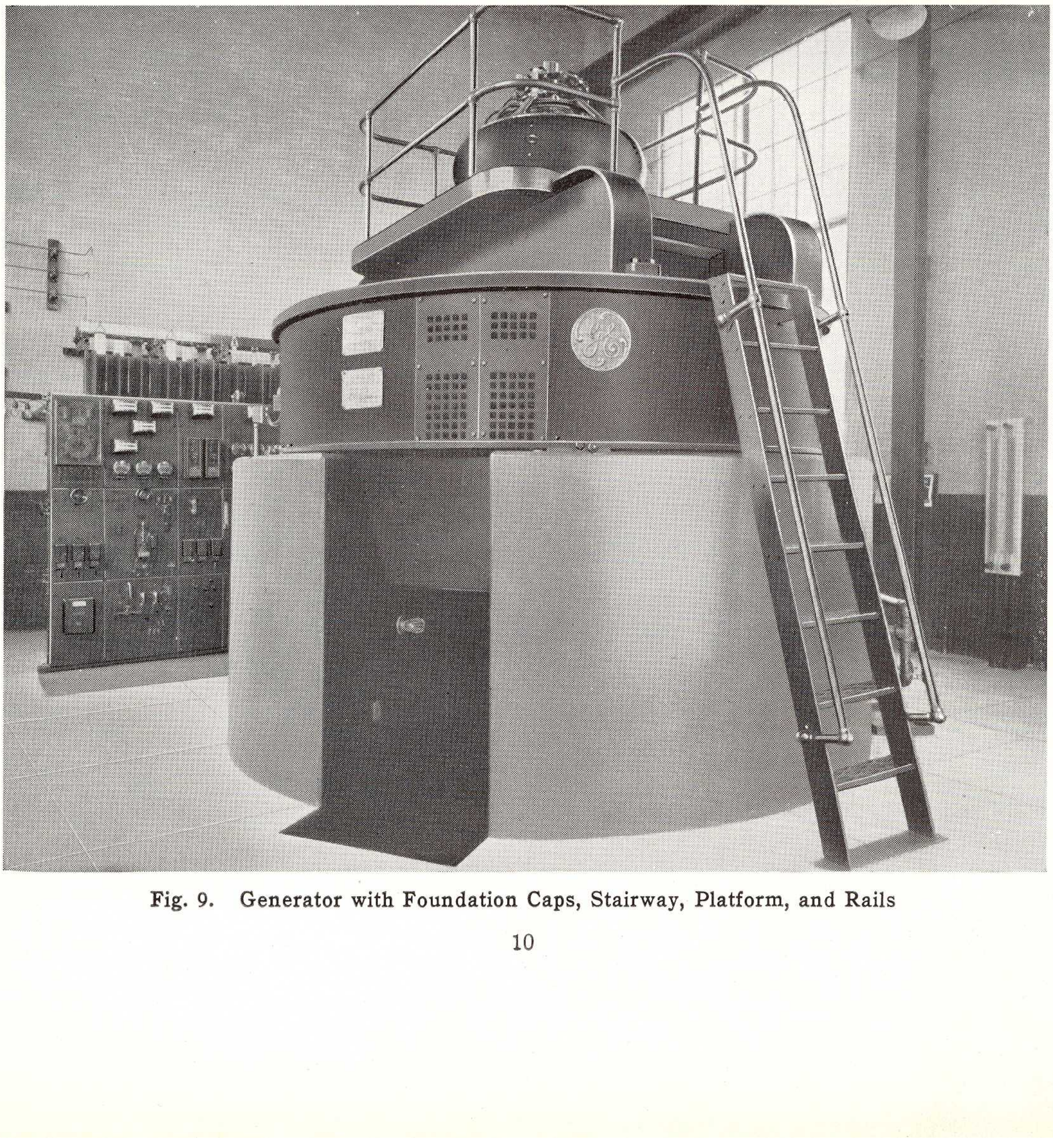


Fig. 9. Generator with Foundation Caps, Stairway, Platform, and Rails